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MOTION SICKNESS SUSCEPTIBILITY: A RETROSPECTIVE COMPARISON OF LABORATORY TESTS

J. Michael Lentz and Fred E. Guedry, Jr.

December 1977

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NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY
PENSACOLA, FLORIDA

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Vestibular system
Motion sickness
Laboratory tests

A test battery designed primarily to assess vestibular function has been used for several years to evaluate individuals referred to our laboratory. Because some of the test conditions have proved to be nauseogenic to some individuals, methods of assessing disturbance during these procedures have been used to pursue a second goal, viz., the estimation of motion sickness susceptibility. This report, which focuses on the latter goal, is a retrospective comparison of results on three tests obtained from two groups of subjects, one of which was a group of Navy and Marine aviation personnel who had suffered multiple attacks of airsickness.

Results from three laboratory tests of motion sickness susceptibility indicated that there are substantial differences between the airsick group and the unselected comparison group on observer ratings and individual self-ratings of motion sickness symptoms. The provocative stimuli in each laboratory test as well as suggestions concerning how multiple tests may prove effective in predicting motion sickness are discussed.

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Naval Medical Research and Development Command
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13 December 1977

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SUMMARY PAGE

THE PROBLEM

A test battery designed primarily to assess vestibular function has been used for several years to evaluate individuals referred to our laboratory. Because some of the test conditions have proved to be nauseogenic to some individuals, methods of assessing disturbance during these procedures have been used to pursue a second goal, viz., the estimation of motion sickness susceptibility. This report, which focuses on the latter goal, is a retrospective comparison of results on three tests obtained from two groups of subjects, one of which was a group of Navy and Marine aviation personnel who had suffered multiple attacks of airsickness.

FINDINGS

Results from three laboratory tests of motion sickness susceptibility indicated that there are substantial differences between the airsick group and the unselected comparison group on observer ratings and individual self-ratings of motion sickness symptoms. The provocative stimuli in each laboratory test as well as suggestions concerning how multiple tests may prove effective in predicting motion sickness are discussed.

INTRODUCTION

A test battery designed primarily to assess vestibular function has been used for several years to evaluate individuals referred to our laboratory. Because some of the test conditions have proved to be nauseogenic to some individuals, methods of assessing disturbance during these procedures have been used to pursue a second goal, viz., the estimation of motion sickness susceptibility. This report, which focuses on the latter goal, is a retrospective comparison of results on three tests obtained from two groups of subjects, one of which was a group of Navy and Marine aviation personnel who had suffered multiple attacks of airsickness.

PROCEDURE

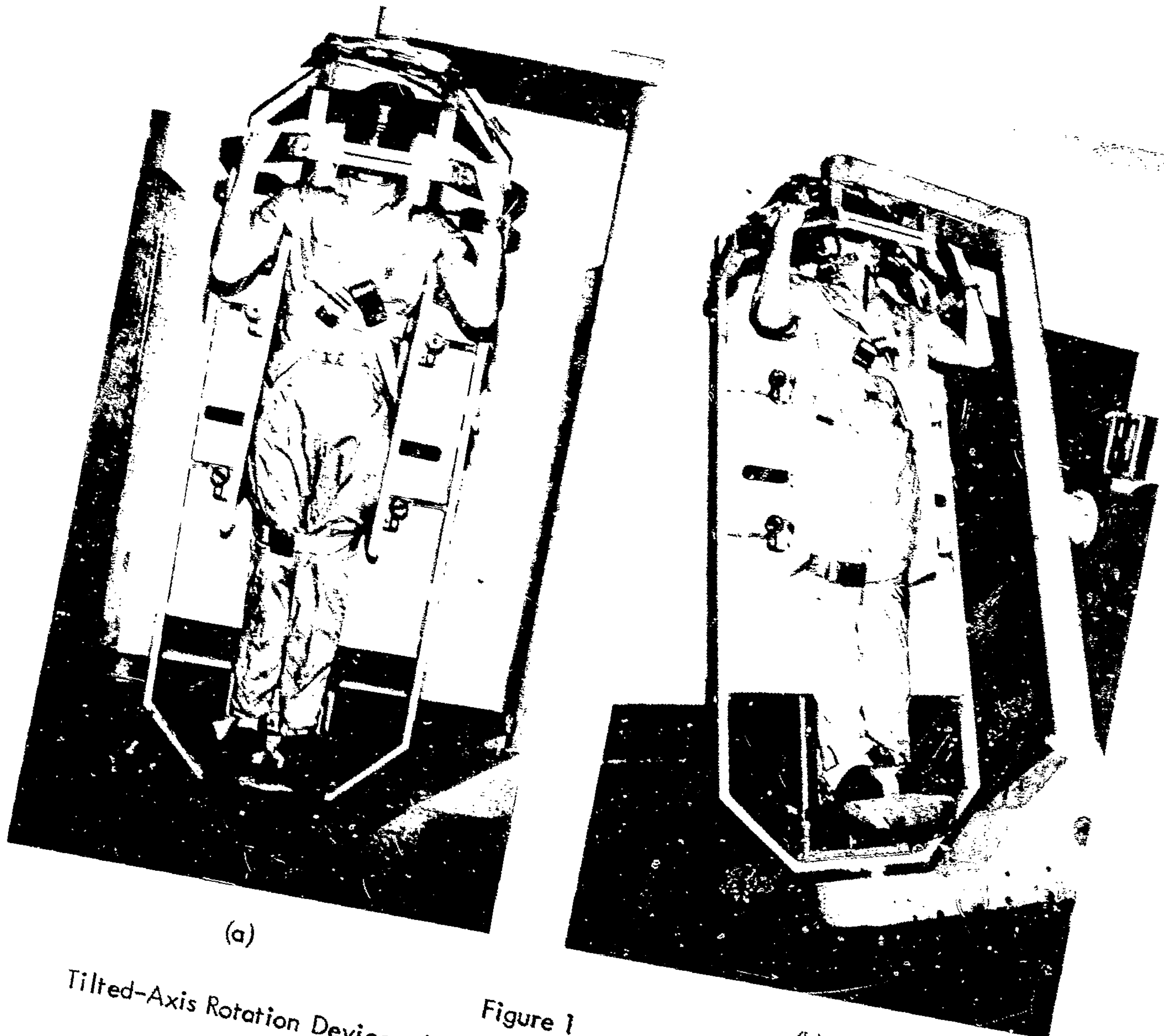
SUBJECTS

Subjects were 127 male Navy and Marine Corps officers and enlisted men. The airsick group consisted of 47 officers who, during training, had experienced airsickness on several occasions and had been referred for this reason. The comparison group consisted of 80 enlisted men who had volunteered to serve as experimental subjects.

METHOD

The tests being compared were the Brief Vestibular Disorientation Test (BVDT), the Tilted-Axis Rotation Test (TART), and the Visual-Vestibular Interaction Test (VVIT). The three tests were part of a battery of clinical tests given to both groups. The order of test administration was TART, BVDT, and VVIT, with a minimum intertest rest interval of 4 hours. The main purpose of testing was evaluation of individuals referred, and this precluded experimental design manipulation such as counterbalancing the order of test administration, et cetera. Subjects were typically tested over a 2-day period. In a few cases, scheduling restraints or equipment failure prevented completion of all tests.

In the TART the erectly standing subject was securely fastened in a litter device capable of rotation about an axis that could be varied in orientation relative to gravity (6,7). The subject was blindfolded and tested in a darkened room. In the first trial the subject was accelerated at 25 deg/sec^2 in a clockwise (CW) direction with the axis of rotation vertical, i.e., aligned with gravity (Figure 1). The acceleration was terminated upon reaching 60 deg/sec (10 rpm), and this constant velocity was maintained for 90 seconds. Following the constant velocity period, the subject was decelerated at 25 deg/sec^2 to a stop. The second trial was identical to the first, with the exception that rotation started in a counterclockwise (CCW) direction. In the third and fourth trials the axis of rotation was tilted 30 degrees off-vertical (Figure 1); and with the axis remaining tilted, the rotation velocities and accelerations as described in Trials 1 and 2 were repeated. The subject was always stopped in the nose-up position. In the fifth and sixth trials the subject remained tilted at 30 degrees off-vertical and again was accelerated at 25 deg/sec^2. A constant velocity of



(a) (b)

Figure 1

Tilted-Axis Rotation Device: (a) vertical position; (b) 30 degrees off-vertical

102 deg/sec (17 rpm) was used for this pair of trials. The interval between trials was approximately 5 minutes. Miller and Graybiel (10) used a similar stimulus in connection with studies of motion sickness.

Aside from the nature of the stimulus, several factors may have influenced signs and symptoms of motion sickness in this test. Eye movements recorded during this procedure as a part of the over-all evaluation are not considered in this report. However, it is pertinent to note that mental arithmetic was used to maintain alertness because of its influence on nystagmus recordings (5,14), and that mental arithmetic may reduce the probability of motion sickness in a short exposure (6). Possibly counteracting the ameliorative effect of mental arithmetic is the fact that each subject was informed that he could stop the test at any time and that he should stop if vomiting was imminent. After each trial the experimenter visually and verbally inspected the subject regarding his condition.

The BVDT procedure, described in detail by Ambler and Guedry (1-3), involved passively rotating an erectly seated subject, with eyes closed, at a constant 90 deg/sec (15 rpm). After 30 seconds at constant velocity the subject made head movements of 45 degrees (Figure 2). The subject was directed to assume a new head position every 30 seconds according to the following order: head right, upright, head left, upright, head right, upright, head left, upright, head forward, upright. On completion of this sequence (rotation time — 330 sec) the chair was stopped, and the subject was instructed to open his eyes after the sensation of movement had subsided.

In the VVIT (11) the erectly seated subject was passively and sinusoidally oscillated* at 0.02 Hz with a peak angular velocity of $\pm$ 155 deg/sec. The axis of rotation was vertical and the subject was encapsulated within a chamber (Figure 3) which remained completely dark until presentation of the visual display. The visual display (17.5 cm x 17.5 cm) shown in Figure 4 was mounted at eye level approximately 86 cm in front of the subject and was illuminated by two small light bulbs on either side of the subject's head and shielded from his eyes. Voltage was adjusted so as to achieve an illumination of 0.165 ft-L on the white ground of the display, as measured by a MacBeth illuminometer. Height of each individual digit was 0.48 cm, while the width averaged about 0.32 cm. In visual arc the subtended digit dimensions were 13 min x 20 min. Spacing within and between rows and columns was 1.27 cm.

The subject was instructed to use the coordinate system to find the corresponding digit embedded within the matrix. Once the digit was located, the subject's task was to verbally report it along with the next two digits below it. (See Appendix A for instructions.) Coordinates were issued via a taped cassette recording every 7 seconds, with a total of 42 taped commands.

Following each test the subject completed a brief self-rate questionnaire concerning his reaction to the test and was rated by observers for symptoms of motion sickness. The rater and self-rate items were identical for BVDT and TART; however, there were some minor modifications to these items on the VVIT. The self-rate items

---

*All subjects had near-perfect performance on the matrix task during a pre-experiment stationary trial.

(a)

(b)

Figure 2

Brief Vestibular Disorientation Device. Subject's head in the upright (a) and Left-tilted (b) positions

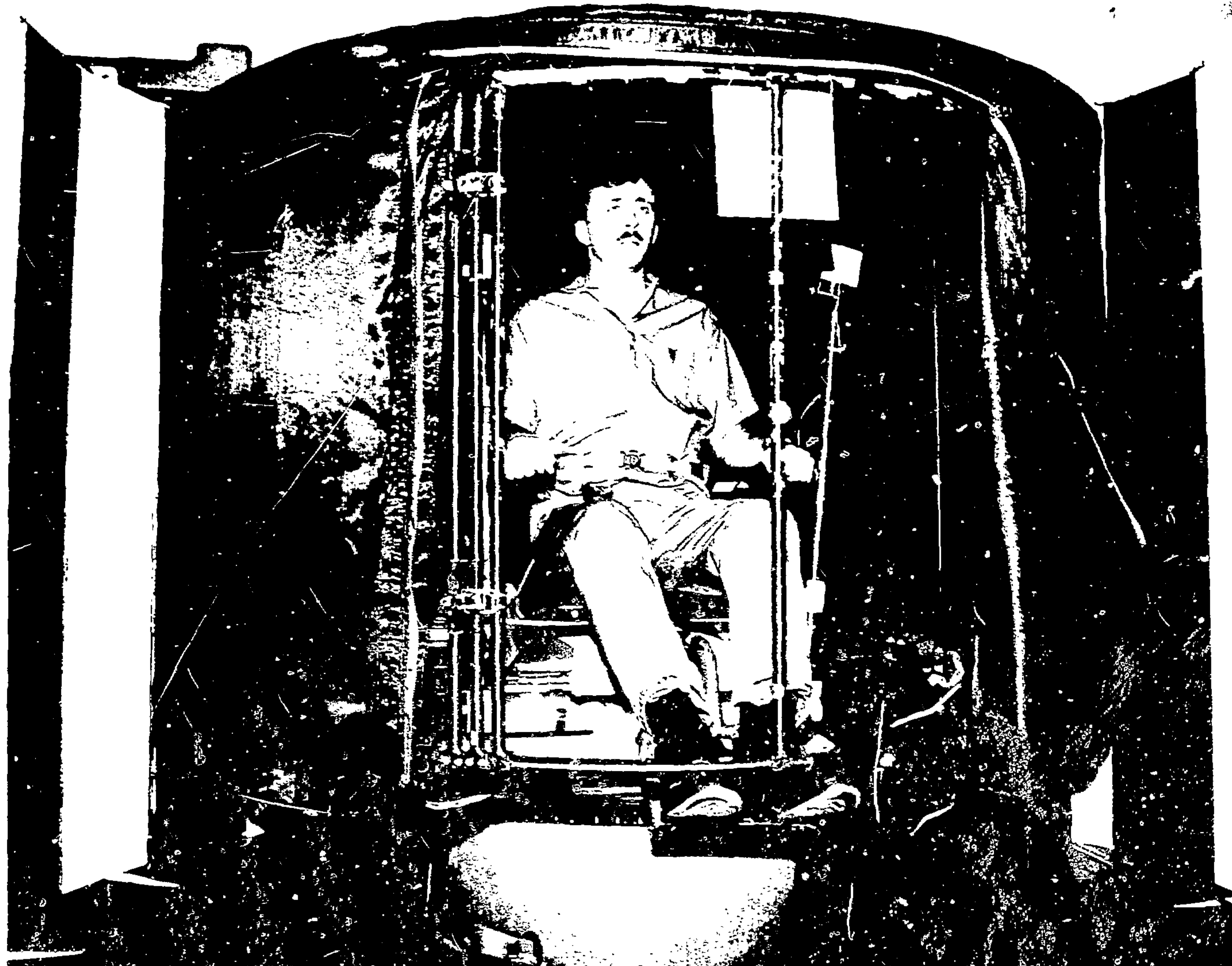


Figure 3

Visual-Vestibular Interaction Test Device
During testing the black shroud completely occluded the subject's external visual reference.

	A	B	C	D	E	F	G	H	I	J	K	L
1	7	1	1	8	2	4	3	1	6	6	9	4
2	6	4	4	2	4	3	1	8	9	7	4	1
3	2	2	3	4	7	8	6	5	1	4	8	5
4	9	9	5	4	6	2	7	3	8	3	7	9
5	8	1	4	3	6	5	7	7	1	4	2	6
6	7	4	7	1	8	1	9	6	3	2	8	5
7	1	7	6	7	6	4	9	5	4	8	3	7
8	7	1	3	3	4	8	9	4	2	5	6	8
9	6	2	1	6	7	3	8	9	7	2	6	6
10	1	7	5	9	9	1	5	6	6	3	5	8
11	9	3	6	7	3	2	2	8	4	5	2	5
12	2	7	6	2	9	9	3	4	1	5	1	7

Figure 4

VVIT Visual Display

were based on a 7-point scale, with 1 indicating favorable or no reaction and 7 indicating extreme reaction. The self-rate items were: like/dislike, no stomach effects/strong stomach effects, no dizziness/strong dizziness, no sickness feelings/strong sickness feelings, steady/very unsteady, no temperature change/feel hot or cold, and not sweating/wet. For the VVIT the steady/very unsteady item was replaced with no headache/bad headache.

The rater items were based on a 10-point scale, with 1 indicating little or no effect and 10 a very strong effect. The rater items were: pallor, sweating, facial expression, unsteadiness, slow recovery, and over-all reaction. For the VVIT two additional items were included: pretest anxiety and disorientation. One observer rated symptoms in the VVIT and TART, whereas three raters (average) were used for the BVDT. The raters were aware of subject classification (airsick referral versus comparison subject).

RESULTS

Since it is not uncommon for subjects to terminate the TART prior to its completion, the rater and self-rate scores were weighted with respect to the number of trials completed (Figure 5). Rater and self-rate scores of individuals completing six trials were multiplied by 0.65, since approximately 65 percent of comparison subjects completed six trials. In a similar manner the scores of individuals completing five trials were multiplied by 0.73, four trials were multiplied by 0.90, and three trials were multiplied by 0.98. Subjects who were unable to complete an off-vertical trial (third trial) were assigned their raw scores. This method of weighting rater and self-rate scores on the TART is arbitrary and may need future revision.

Summary data for the airsick and comparison groups, including conventional _t_-test comparisons, are presented on an item basis in Tables I and II. There was a significant difference between the comparison and airsick groups on all rater items (Table I) with the exception of pretest anxiety, pallor,* and sweating on the VVIT. There was a significant difference between the groups on all self-rate items (Table II) with the exception of the hot-or-cold to no-temperature-change item on the BVDT. Total score cumulative distributions for each test are presented in Figures 6, 7, and 8.

Inter- and intratest correlations on total scores for the comparison and airsick groups are presented in Tables III and IV, respectively. It is apparent that the group of control subjects (Table III) have highly significant inter- and intratest correlations. Inspection of the data from the airsick group (Table IV) reveals a different result. In this instance, the rater and self-rate scores are significantly correlated with each other within each of the laboratory tests; however, only one intertest correlation was significant, BVDT rater to VVIT rater.

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*Subjects are not visible to the rater during the VVIT, and the observer's ratings are based upon a view of the subject about 1 min after the exposure is completed. Ratings of pallor in this test are based upon post-exposure observation.

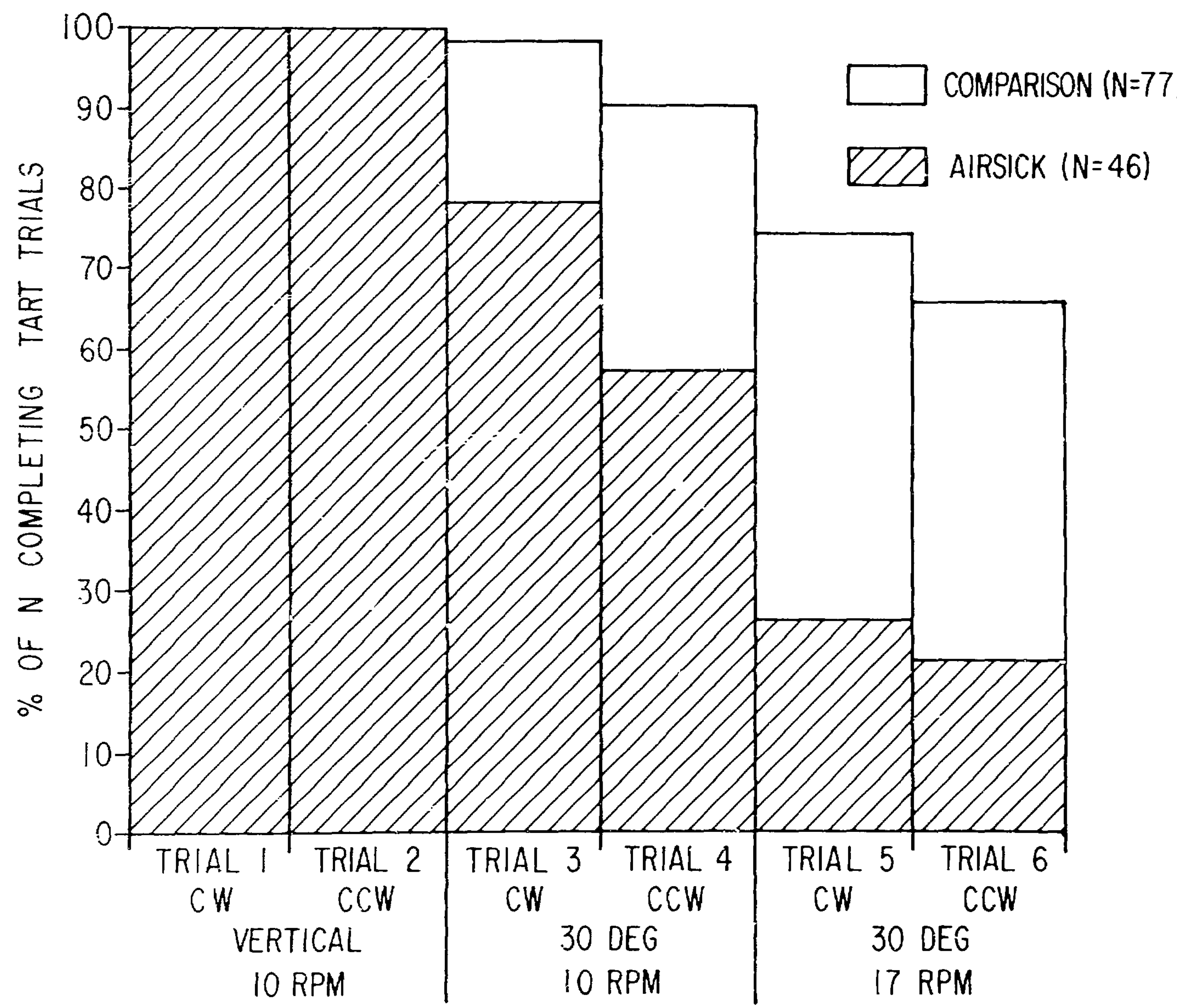

Figure 5
Percentage of comparison and airsick subjects completing TART trials

Table I

Summary of Rater Evaluations for Comparison and Airsick Groups

Item	VVIT Comparison Mean (SD)	VVIT t	VVIT Airsick Mean (SD)	BVDT Comparison Mean (SD)	BVDT t	BVDT Airsick Mean (SD)	TART (weighted) Comparison Mean (SD)	TART (weighted) t	TART (weighted) Airsick Mean (SD)
Pretest Anxiety	2.12	1.95	2.69	--	--	--	--	--	--
	(1.50)		(1.68)	--		--	--		--
Disorientation	2.03	2.29	2.64	--	--	--	--	--	--
	(1.28)	*	(1.68)	--		--	--		--
Pallor	2.73	1.60	3.18	2.62	5.50	3.49	2.46	4.80	3.98
	(1.50)		(1.51)	(1.37)	***	(1.57)	(1.48)	***	(1.95)
Sweating	2.84	1.88	3.44	2.79	5.43	3.78	2.73	3.01	3.70
	(1.53)		(1.96)	(1.59)	***	(1.80)	(1.64)	**	(1.83)
Facial Expression	2.34	2.72	3.20	2.50	8.15	4.33	1.81	4.90	3.25
	(1.49)	**	(1.98)	(1.87)	***	(2.36)	(1.26)	***	(1.92)
Unsteadiness	2.35	2.44	3.07	2.28	7.81	3.65	1.68	4.86	2.97
	(1.45)	*	(1.74)	(1.27)	***	(2.07)	(0.99)	***	(1.94)
Slow Recovery	2.04	3.49	3.02	2.38	6.11	3.65	1.60	5.13	3.27
	(1.15)	***	(1.96)	(1.77)	***	(2.13)	(1.06)	***	(2.48)

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Continuation of Table I

Item	VVIT Comparison Mean (SD)	VVIT t	VVIT Airsick Mean (SD)	BVDT Comparison Mean (SD)	BVDT t	BVDT Airsick Mean (SD)	TART (weighted) Comparison Mean (SD)	TART (weighted) t	TART (weighted) Airsick Mean (SD)
Over-All	3.08 (2.75)	3.36 **	5.02 (3.59)	2.80 (2.15)	7.19 ***	4.63 (2.64)	2.16 (1.53)	6.28 ***	4.71 (2.94)
Total Score	19.52 (10.82)	3.07 **	26.27 (13.07)	15.37 (8.66)	8.05 ***	23.53 (10.34)	12.32 (7.24)	5.79 ***	21.88 (10.89)

* $p < .05$
** $p < .01$
*** $P < .001$

Table II

Summary of Self-Rate Evaluations for Comparison and Airsick Groups

Item	VVIT Comparison Mean (SD)	VVIT t	VVIT Airsick Mean (SD)	BVDT Comparison Mean (SD)	BVDT t	BVDT Airsick Mean (SD)	TART (weighted) Comparison Mean (SD)	TART (weighted) t	TART (weighted) Airsick Mean (SD)
Like/Dislike	3.16 (1.90)	5.78 ***	5.13 (1.69)	2.71 (1.82)	7.89 ***	5.25 (1.66)	1.89 (1.48)	8.76 ***	4.60 (1.87
Stomach Effects	2.80 (1.91)	5.26 ***	4.69 (1.95)	2.58 (2.07)	4.99 ***	4.33 (1.64)	2.24 (1.78)	8.57 ***	4.95 (1.47)
Dizziness	3.13 (2.12)	5.51 ***	5.18 (1.75)	2.99 (1.78)	5.63 ***	4.81 (1.76)	1.76 (1.42)	6.87 ***	3.88 (1.94)
Sickness Feelings	2.58 (1.91)	6.76 ***	4.96 (1.83)	2.47 (2.01)	6.00 ***	4.54 (1.68)	2.25 (1.76)	8.20 ***	4.86 (1.55)
Steady	--- ---	---	--- ---	2.67 (1.89)	4.98 ***	4.31 (1.65)	1.65 (1.34)	7.20 ***	3.71 (1.77)
Hot/Cold - No Temp. Change	3.11 (2.19)	3.39 ***	4.52 (2.25)	3.66 (2.14)	1.87	4.49 (2.02)	2.69 (1.85)	3.75 ***	4.05 (2.63)
Dry-Wet	2.90 (1.98)	2.65	3.98 (2.49)	4.14 (1.99)	2.86 **	5.20 (1.26)	3.05 (1.63)	5.08 ***	4.58 (1.51)

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Continuation of Table II

Item	VVIT Comparison Mean (SD)	VVIT t	VVIT Airsick Mean (SD)	BVDT Comparison Mean (SD)	BVDT t	BVDT Airsick Mean (SD)	TART (weighted) Comparison Mean (SD)	TART (weighted) t	TART (weighted) Airsick Mean (SD)
Headache	1.49	4.25	2.60	---	---	---	---	---	---
	(1.12)	***	(1.78)	---		---	---		---
Total Score	19.18	6.34	30.96	19.84	5.21	30.31	15.54	8.38	30.62
	(9.96)	***	(9.92)	(11.58)	***	(9.93)	(9.48)	***	(9.59)

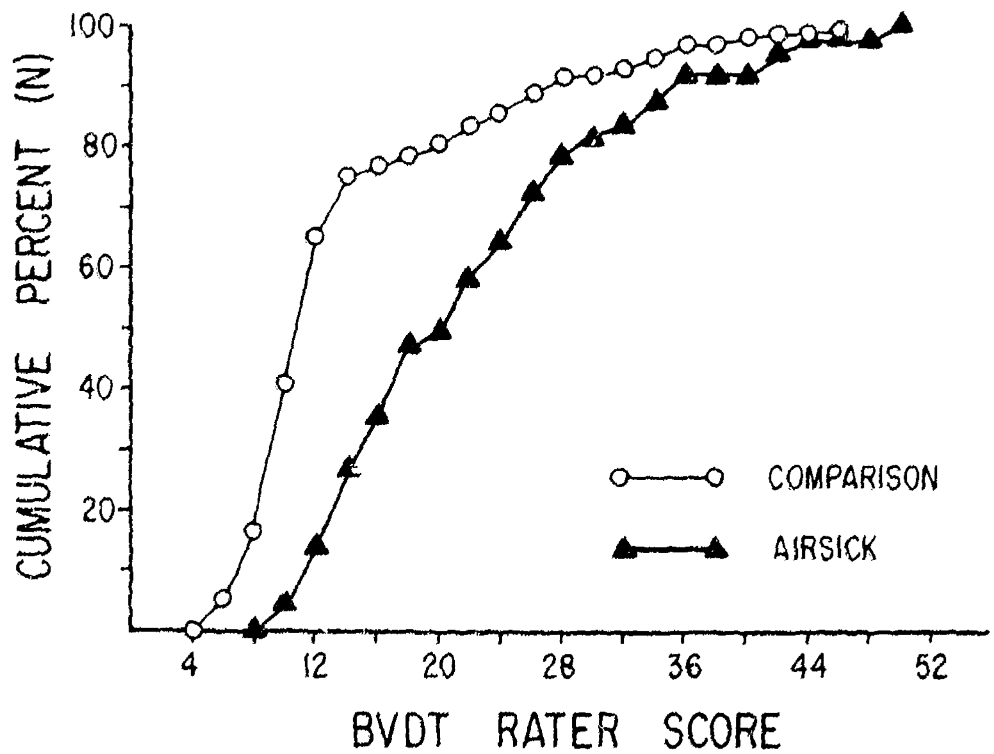
* p < .05
** p < .01
*** p < .001

Table III

Correlation Matrix for Comparison Subjects

		BVDT		TART		VVIT	
		Rater	Self-rate	Rater	Self-rate	Rater	Self-rate
BVDT	Rater	---	.57***	.63***	.49***	.56***	.45***
	Self-rate		---	.52***	.70***	.41***	.60***
TART	Rater			---	.76***	.46***	.37***
	Self-rate				---	.38***	.53***
VVIT	Rater					---	.68***
	Self-rate						---

*** $p < .001$



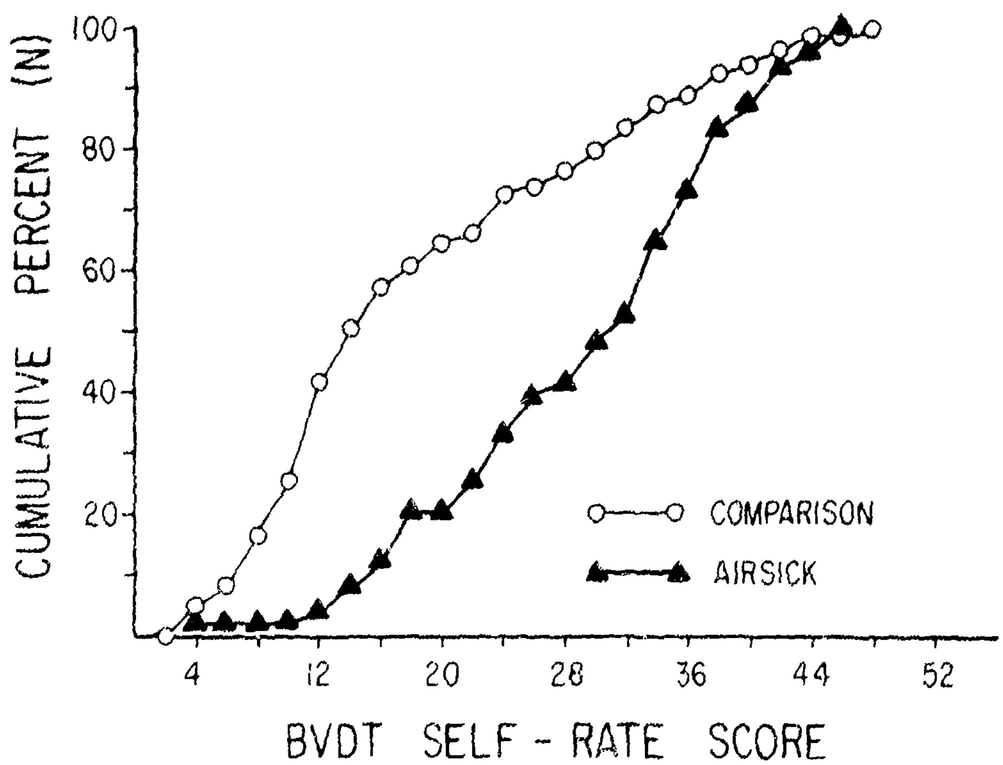


Figure 6

Cumulative percent distributions for BVDT rater and self-rate scores

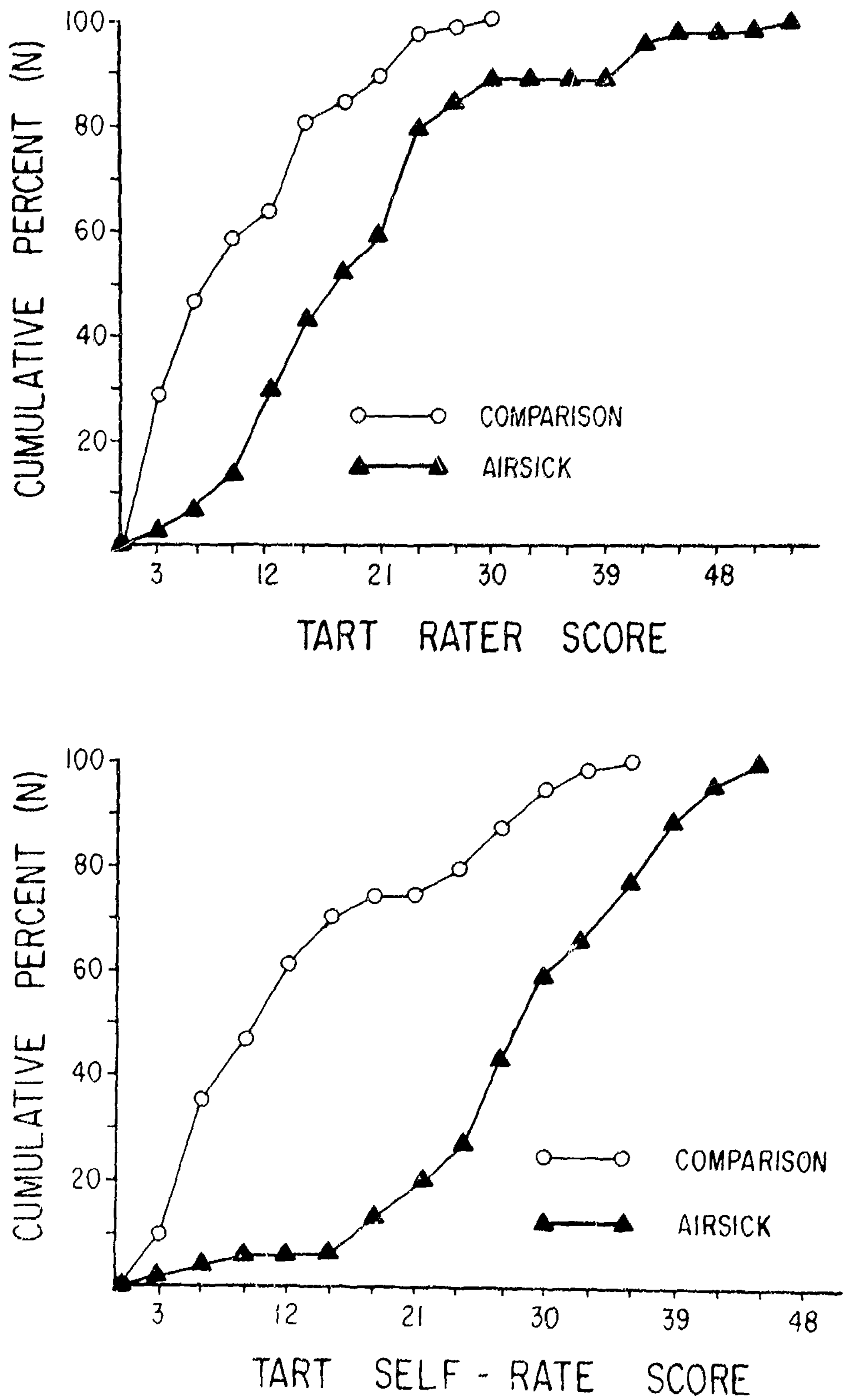


Figure 7

Cumulative percent distributions for TART rater and self-rate scores

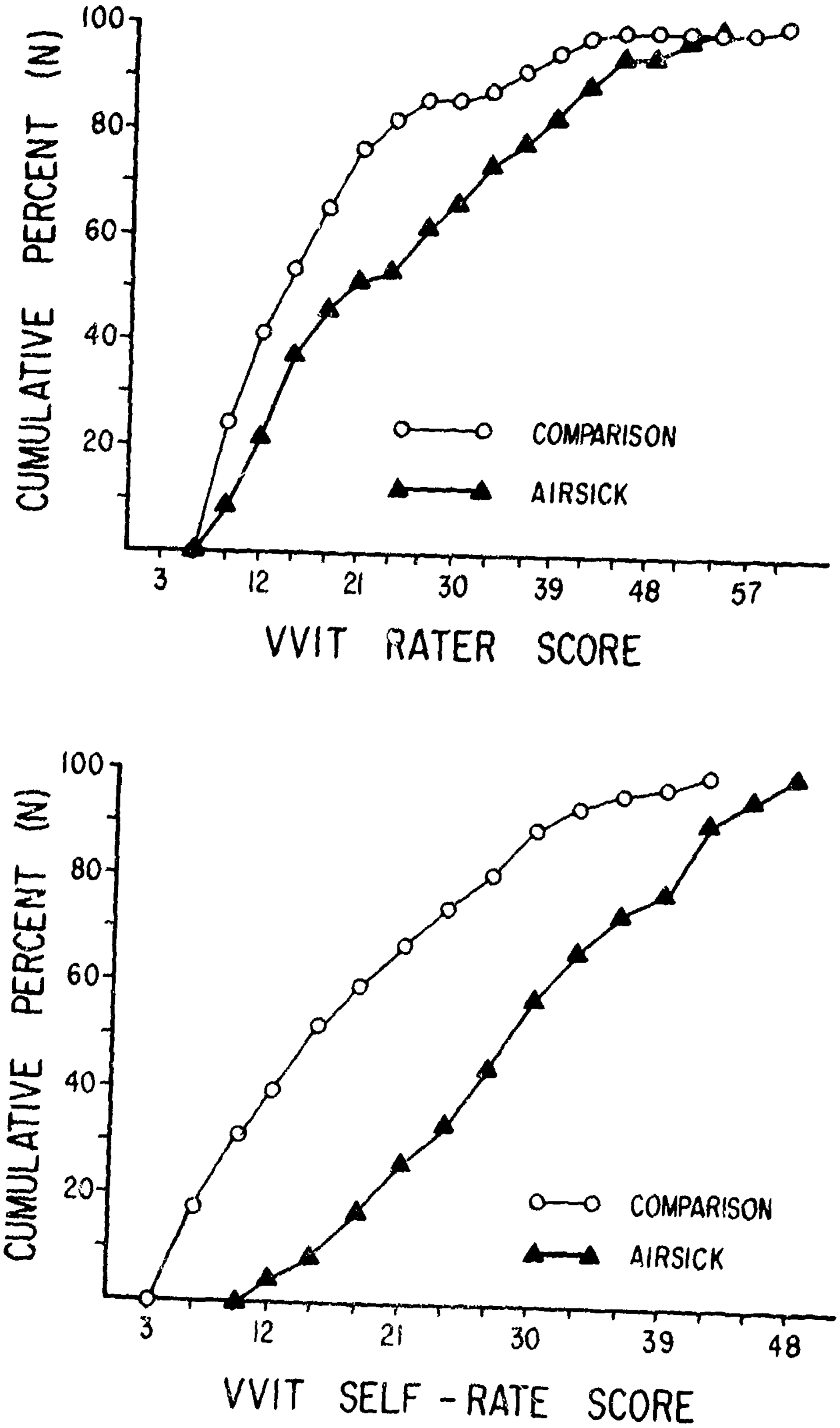


Figure 8

Cumulative percent distributions for VVIT rater and self-rate scores

Table IV

Correlation Matrix for Airsick Subjects

		BVDT		TART		VVIT	
		Rater	Self-rate	Rater	Self-rate	Rater	Self-rate
BVDT	Rater	---	.53***	.20	.25	.48***	.26
	Self-rate		---	.22	.20	.23	.21
TART	Rater			---	.64***	.15	.02
	Self-rate					.24	.24
VVIT	Rater					---	.64***
	Self-rate						---

*** $p < .001$

DISCUSSION

There are differences in the provocative stimuli used in the three tests, although methods of assessing disturbance in the tests were very similar. The BVDT assesses signs of disturbance produced by Coriolis cross-coupling stimuli. Such stimuli set off semicircular canal responses in a plane at right angles to concurrent otolith signals (8). In some individuals this stimulus induces an immediate fear reaction, sometimes accompanied by nausea and vomiting. In other individuals initial reactions may not be strong, but nausea builds up with successive stimuli. By contrast, early in an exposure to the TART stimulus, there is usually little or no immediate disturbance but rather mild interest in the perceived body movement, which differs from that expected by the subject. However, as rotation is sustained, the initial relatively comfortable experience gives way, in a number of individuals, to a mild nausea which then may build rapidly into motion sickness. The exact nature of the TART stimulus is still in question; however, according to classical vestibular theory, as off-vertical rotation commences, the semicircular canals and otolith organs would yield "concordant" signals of rotation. After rotation has been sustained for about 40 seconds, the semicircular canal input would have returned to near baseline level, yet nystagmus is augmented throughout off-vertical rotation and persists far beyond its expected decay (6,7). It is possible that the augmented response as well as the nauseogenic effects that develop during this prolonged (90 second) rotation is attributable to otolithic modulation of the spontaneous ampullary nerve input (cf. Benson, ref. 4, for overview of alternatives). Moreover, during each deceleration from the four periods of off-vertical rotation that constitute this test, the semicircular canal signals and otolith change-in-position signals are in direct opposition, and once rotation has stopped, otolith position signals suppress effects of, and are discordant with, the semicircular canal postrotational input (4). Effects of deceleration tend to exacerbate symptoms that may have built up during the rotation period, but the rest period between each rotation provides some time for recovery. The TART stimulus differs from the BVDT stimulus in that it typically does not produce immediate indications of disturbance or fear, but rather is one that seems mild at first and then may gradually become nauseogenic. In both the BVDT and TART there is reason to suspect that central integration of discordant canal and otolith information is elementary to the provocative nature of the stimulation.

The VVIT procedure differs from the BVDT and TART in that it involves a nauseogenic visual-vestibular conflict. During low-frequency sinusoidal variation in angular velocity, like that used in the VVIT, vestibular nystagmus peaks and is in many subjects sufficient to degrade visual performance for some interval during each half-cycle. Visual inspection of different parts of any sizeable display is accomplished with saccadic eye movements. When the saccades of vestibular nystagmus are superimposed on those of voluntary fixation shifts, errors in eye positioning occur; and when the nystagmus slow phase velocity is sufficient, blurring of vision also occurs. Inspection of complex visual displays under these circumstances is nauseogenic although the motion stimulus itself with simpler displays or in darkness is generally not disturbing. With this type of stimulation, the nausea tends to build gradually with successive cycles, even though the visual blurring is evident as soon as it occurs.

The visual-vestibular conflict is a periodic exposure to the kind of disturbance that many people have experienced while reading in an enclosed moving vehicle. It is comparable to one kind of visual-vestibular conflict that some Naval Flight Officers experience in the performance of their duties.

The high rater/self-rate intratest correlations for all tests in both groups suggest a substantial agreement between observer ratings and subjects' self-ratings of motion sickness and tend to negate the possibility that one group was any more or less likely than the other to purposefully bias their self-reports. The significant differences between airsick and comparison groups provide further validation of the BVDT, previously validated primarily against a pass/fail criterion (1-3), and also suggest that the TART and VVIT may be useful in evaluating individual susceptibility to motion sickness.

Most of the individual items on both rater and self-rate forms significantly differentiated the comparison and airsick groups. For the self-rate scale the "like/dislike" item appeared to be the best differentiator of the groups, whereas the "feel-hot-or-cold" item was least effective. For the rater scale the "over-all" item appeared the best, whereas "sweating" was perhaps the least effective discriminator of the groups. Inadequate air conditioning control may have contributed spurious variation.

The inter- and intratest correlations within the comparison group would seem to suggest that the three tests are, at least in part, measuring the same characteristic and thus, to some degree, may be redundant. The correlations between the BVDT and VVIT for the comparison group have been confirmed in tests on a separate group of 50 officers in flight training (12) and in another group of 299 Naval Flight Officers (9). The same laboratory tests on airsick referrals suggested a different conclusion. In this case the intratest measures were strongly related, but the intertest correlations were generally not significant.

The low, generally insignificant, intertest correlations in the airsick referral group is a curious fact. An immediate statistical presumption would be that the scores of the airsick group were restricted in range, thereby yielding insignificant intertest correlations. However, if severely restricted ranges were the sole explanation, then intratest (rater/self-rate) correlations should also be substantially lower in the airsick group, but they were approximately of the same magnitude and they remained highly significant statistically ($p < .001$). There is, however, a difference in the distributions of "airsick" versus comparison group scores. All comparison group distributions are skewed toward the low end of the distributions (Figures 6,7,8). The number of subjects in the airsick group is relatively small for estimating the distributions of scores, but perusal of these distributions indicates that there was a considerable range of scores among airsick referrals on each test, but very few scores fell at the low end of the distributions.

Our experience with individuals participating in procedures involving these kinds of motion stimuli suggests several interpretations from among many possibilities.

individuals exposed from time to time to any one of these stimulus situations vary somewhat in their reactions. It is possible that the typical airsick referral is an individual who has a high probability of exhibiting and experiencing strong reactions on any given exposure, but who also may be only slightly disturbed on some occasions. This would account for the high intratest (rater/self-rate) correlations in the airsick referral group and the lower and generally nonsignificant intertest correlations in this group. Why, then, have we found the fairly high intertest correlations in the comparison group? It appears that a sample, unselected with reference to airsickness, will naturally include a preponderance of individuals who have low probability of exhibiting high reactivity during any given short exposure to provocative motion stimuli. Since the comparison group was obtained without reference to airsickness, it would naturally also include some individuals who are "airsick types," and who therefore would have a high probability of giving high scores on two of the three tests and occasionally on all three tests. Thus there would be a strong anchoring of cases at the low end of each continuum and yet sufficient range at the high end to yield significant intertest correlations in comparison groups. Another factor that may be operating in the airsick group is suggested by occasional individuals who seem exceptionally disturbed by one stimulus mode and yet are undisturbed by other stimulus modes. This has been apparent to a pronounced degree in a few individuals tested; in one or two laboratory personnel who evidenced this profile, the specificity of disturbance seemed to be an enduring characteristic. It is possible, then, that some airsick referrals are specifically disturbed only by certain idiosyncratic parameters of the total motion stimulus, and hence only by one of our several different tests. This would introduce additional intertest variability into the airsick group and, coupled with the other possibilities suggested above, could quite easily account for the relatively high intratest correlations and low intertest correlations in the airsick group. It should be noted that either of these interpretations indicates that several tests of motion reactivity would be advantageous over a single test in any effort to predict airsickness susceptibility. In this connection, deriving a score for each subject by simply summing all scores (rater and self-rate) on all tests provides a more definitive separation of the airsick group from the comparison group than does any single measure. With this score, only two members of the airsick group had a score as low as the mean of the comparison group.

The usefulness of this total score approach is limited due to the inclusion of self-rate scores which can be subject to biased reporting. For instance, most students in aviation training programs are highly motivated individuals who want to "fly" and, as a result, work diligently for the opportunity. The practicality of self-ratings is subject to doubt, especially if these highly motivated students suspect that their self-rates (reports) on motion sickness susceptibility tests could result in attrition from the flight program. This bias was probably not operating in either of our groups because of the testing circumstances.

In their current form these tests do not assess after-reactions, adaptive capacity, or adaptive retention. The latter two characteristics, according to Reason and Brand (13) are partially independent of one another and hence important factors to be assessed. Recent data on after-reactions to provocative tests (9) have shown that in

some individuals, strong motion sickness symptoms persist for several hours after exposure. One recently tested individual evidenced only minor symptoms during and immediately following the BVDT; however, these symptoms increased in severity to the point of vomiting approximately 30 minutes after the test. This individual later attrited from the in-flight stage of flight training due to airsickness problems. After-reactions, and adaptive capacity and retention, are important concepts that need to be developed in future studies.

REFERENCES

1. Ambler, R. K., and Guedry, F. E., Validity of a brief vestibular disorientation test in screening pilot trainees. Aerospace Med., 37:124-126, 1966.

2. Ambler, R. K., and Guedry, F. E., Cross-validation of a brief vestibular disorientation test administered by a variety of personnel. Aerospace Med., 39:603-605, 1968.

3. Ambler, R. K., and Guedry, F. E., Reliability and validity of the Brief Vestibular Disorientation procedure compared under 10 rpm and 15 rpm conditions. Aerospace Med., 42:186-189, 1971.

4. Benson, A. J., Modification of the response to angular accelerations by linear acceleration. In: Kornhuber, H. H. (Ed.), Handbook of Sensory Physiology, Vol. VI/2. Berlin/Heidelberg/New York: Springer-Verlag, 1974. Pp 281-320.

5. Collins, W. E., and Guedry, F. E., Arousal effects and nystagmus during prolonged constant angular acceleration. Acta otolaryng., 54:349-362, 1962.

6. Correia, M. J., and Guedry, F. E., Modification of vestibular responses as a function of rate of rotation about an earth-horizontal axis. Acta otolaryng., 62:297-308, 1966.

7. Guedry, F. E., Effects of concomitant stimulation of the semicircular canals and otoliths by "barbecue spit" rotation, rotation about a tilted axis, and other forms of stimulation. Excerpta Med. Int. Cong. Ser. 206 (Amsterdam), 1970.

8. Guedry, F. E., Psychophysics of Vestibular Sensation. In: Kornhuber, H. H. (Ed.), Handbook of Sensory Physiology, Vol. VI/2. Berlin/Heidelberg/New York: Springer-Verlag, 1974. Pp 1-154.

9. Lentz, J. M., Holtzman, G. L., Hixson, W. C., and Guedry, F. E., Normative data for two short tests of motion reactivity. NAMRL-1243. Pensacola, FL: Naval Aerospace Medical Research Laboratory, 1977.

10. Miller, E. F., II, and Graybiel, A., Perception of the upright and susceptibility to motion sickness as functions of angle of tilt and angular velocity in an off-vertical rotation. In: The Role of the Vestibular Organs in Space Exploration. NASA SP-314. Washington, DC: U. S. Government Printing Office, 1973.

11. Moore, H. J., Lentz, J. M., and Guedry, F. E., Nauseogenic visual-vestibular interaction in a visual search task. NAMRL-1234. Pensacola, FL: Naval Aerospace Medical Research Laboratory, 1977.

12. Prewitt, D. D., Interrelations between measures of motion history, personality, and immediate reactions to unusual motion stimuli. Master's Thesis. Pensacola, FL: University of West Florida, 1975.

13. Reason, J. T., and Brand, J. J., Motion Sickness. New York: Academic Press, 1975.

14. Stockwell, C. W., Guedry, F. E., Turnipseed, G. T., and Graybiel, A., The nystagmus response during rotation about a tilted axis. Minerva Oto., 4: 229-235, 1972.

APPENDIX A

VVIT Instructions

VVIT Instructions

This is a psychological experiment to find out facts about how humans function on certain tasks. Here is how the experiment works. You will be shown a matrix of digits similar to the one below:

	K	G	A	F	I	H	E	J	L	C	B	D
2	5	4	8	6	4	2	1	8	9	6	2	2
9	5	2	8	4	3	8	1	2	4	1	4	6
10	4	8	2	1	1	4	9	5	8	5	2	1
4	2	6	8	7	4	5	1	5	9	8	4	2
12	6	4	5	8	6	9	9	2	1	4	8	1
7	4	9	8	4	4	2	1	8	9	2	5	6
1	6	3	6	9	4	8	2	9	8	1	5	2
5	5	8	6	2	1	9	4	8	3	6	5	4
3	8	2	1	9	4	2	4	9	8	1	6	5
8	6	5	4	2	9	3	5	1	9	5	4	6
6	2	4	1	5	8	6	2	5	8	2	1	3
11	5	8	4	6	2	9	1	6	2	5	9	4

Notice that a sequence of letters and numbers appears at the top and left, respectively, of the matrix. Notice also that any digit inside the matrix can be specified in terms of a column letter and row number. During the experiment you will hear a "letter-number" every seven seconds. This "letter-number" will refer to a letter along the top margin of the matrix and a number along the left margin. Your job will be to find the digit inside the matrix which is beneath the letter and to the right of the number. Then you must call out this digit and the next two digits directly underneath it in the column. Let's take an example. Suppose you heard "E-7." You would go down Column E and across Row 7 and find the digit "1" inside the matrix. Then you would call out, "One, two, four." The object will be to get as many correct numbers as possible. However, if you run out of time on a particular set you must go on to the next set since you will get credit only for the current answer. It is important that you try your hardest in this experiment. The number matrix you will see during the experiment will be dimly illuminated. You must not lean forward to see the display better or use your fingers to find the digits. Instead, you should sit up straight in the chair. It is important that you keep your head still and in the chair's headrest while the chair is moving; otherwise you may become motion sick.

If you have any questions, please save them until the experimenter is ready for you.

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A test battery designed primarily to assess vestibular function has been used for several years to evaluate individuals referred to our laboratory. Because some of the test conditions have proved to be nauseogenic to some individuals, methods of assessing disturbance during these procedures have been used to pursue a second goal, viz., the estimation of motion sickness susceptibility. This report, which focuses on the latter goal, is a retrospective comparison of results on three tests obtained from two groups of subjects, one of which was a group of Navy and Marine aviation personnel who had suffered multiple

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attacks of airsickness.

Results from three laboratory tests of motion sickness susceptibility indicated that there are substantial differences between the airsick group and the unselected comparison group on observer ratings and individual self-ratings of motion sickness symptoms. The provocative stimuli in each laboratory test as well as suggestions concerning how multiple tests may prove effective in predicting motion sickness are discussed.